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(54) Extruding dies and method of extruding ceramic honeycomb structural bodies by using such extruding dies.

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PATENT ABSTRACTS OF JAPAN, vol. 9, n . 290 (M-430)[2013], 16th November 1985; & JP-A-60 129 235 (MATSUSHITA DENKI SANGYO K.K) 10-07-1985

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D s ription

The present invention relates to extruding dies and a method of extruding ceramic honeycomb structural bodies using such extruding dies. More specifically, the invention relates to extruding dies to be used in extruding ceramic honeycomb structural bodies having partition walls of different wall thicknesses, such as catalyst carriers for purifying waste gases from internal combustion engines, heat exchangers, and rotors for pressure wave type superchargers, and to a method of extruding ceramic honeycomb structural bodies using such extruding dies.

Hereinafter, the term "ceramic honeycomb structural bodies" is used to mean structural bodies having a plurality of through holes defined by partition walls.

Various extrusion dies for extruding ceramic honeycomb structural bodies are known. US-A-3905743 describes a die having feed holes 18 and 20 which communicate with shaping channels 24 and 34 respectively. The peripheral surface of the body is formed as the material is extruded through the feed hol s 20 (positioned at the periphery and larger than feed holes 18), which communicate with an annular shaping channel 34. The channel 34 may have a bent section 38 to facilitate the flow of batch material therewithin. For the inner body, straight-sided slots 24 are described as very adequate for extruding ceramic batch materials.

EP-A-4040 discloses a die having a plurality of parallel passageways 24 which communicate with selected areas of discharge 26 so as to deliver the batch material flowing from the extrusion chamber 16 through to the outlet surface 22. The peripheral wall of the honeycomb body is formed by an oblique passageway 51 which intersects the areas of discharge 24. The thickness of the passageway 51 may be changed to provide bodies having outer skins of different thicknesses. It is proposed that this method results in reduced peripheral cell crushing in the body.

EP-A-40052 shows a device having means for varying the skin wall thickness of honeycomb bodies, having a die body 10 which includes a plurality of feed channels 24 which communicate with discharge slots 26. A narrow radial gap 44 extends away from the slots 26 and communicates with a central orifice 38.

US 4368025 shows an extrusion device comprising a die 2, suitable for preparing honeycomb bodies having a thick outer wall. The die 2 has a plurality of circular feed passageways 4 having the same diameter, which communicate with extrusion slots 5. The die has a mask 3 which is provided with an annular wall 32 and with an inner surface 31 ; the surface 31 having a diameter smaller than that of the die 2 on the material outlet side. The outer shape of the body extruded out of the die 2 is formed by the inner surface 31.

In order to increase mechanical strength of an outer peripheral edge portion of a honeycomb structural body which comprises partition walls having at least two different thicknesses and is used as a catalyst carrier for purifying waste gases from an internal combustion engine, it is known that the thickness of the outermost peripheral wall of the honeycomb structural body is increased (see JP-B-54-28,850), and that the thickness of partition walls at an outer peripheral portion of the honeycomb structural body is made greater than that of partition walls at an inner portion thereof (see JP-B-57-50, 170).

As dies for extruding such ceramic honeycomb structural bodies, there have been proposed dies in which a hold plate is provided above an outer peripheral portion of shaping channels corresponding in the sectional configuration of the honeycomb structural bodies to unit partition walls extruded through the shaping channels at the outer peripheral portion, and dies in which ceramic body feed holes are provided at an interval corresponding to the width of shaping channels.

However, the dies of such constructions can be used for extruding honeycomb structural bodies in which through holes are shaped in a relatively simple geometrical sectional shape such as a triangular or rectangular section and the thickness of partition walls does not largely vary. However, ceramic honeycomb structural bodies, such as supercharger rotors, which contain partition walls having two or more different thicknesses and through holes of a complicated section cannot be shaped by extrusion by these dies, because of non-uniform extruing speed of the body.

In order to eliminate the above drawbacks, NGK Insulators, Ltd. have formerly proposed a die for extruding ceramic honeycomb structural bodies as shown in accompanying Figs. 6 and 7 (JP-A-60-67,111). This die comprises shaping channels 2 (2a, 2b, 2c, 2d, and 2e) corresponding to the sectional configuration of the ceramic honeycomb structural body and ceramic body feed holes 3 (3a, 3b, 3c, 3d, and 3e) communicating with the shaping channels at intersecting portions or annular shaping channel portions, wherein the hydraulic diameter of the ceramic body feed holes 3b, 3c and 3d communicating with the shaping channels 2b, 2c and 2d giving thinner partition walls is made greater than that of the ceramic body feed holes 3a, and 3e communicating with the shaping channels giving thicker partition walls.

Since this ceramic honeycomb structural body-extruding die has the above-mentioned construction, the thicker partition walls and the thinner partition walls are shaped at an qual extruding speed. Thus, mechanically strong c ramic honeycomb structural bodies can be obtained.

However, in this extruding die, while the ceramic body is being extrud d, it is rapidly spread at transitional locations between the ceramic body feed

holes 3a and 3e and the wider shaping channels 2a and 2e to form the thicker partition walls. Consequently, adhesion in the body becomes weaker when the partiti n walls are being formed from the body passing through the ceramic body feed holes, and ceramic grains are roughly and non-uniformly charged into an outer peripheral wall and an inner peripheral wall. Accordingly, fine cracks very often occur at inner portions of the partition walls due to the rough charging. When the outer and inner peripheral walls are ground after firing, defects such as scratches or patterns appear and cracks are formed parallel with the extruding direction.

Under the circumstances, the present inventors have made studies to solve the problems encountered by the prior art, and found out that the problems can be solved by bending communicating paths of ceramic body feed holes, which communicate with the shaping channels giving thicker partition walls. The present invention has been accomplished based on this discovery.

According to a first aspect of the present invention, there is provided a die for extruding ceramic honeycomb structural bodies as set out in claim 1.

According to a second aspect of the present invention, there is provided a method for extruding ceramic honeycomb structural bodies from a ceramic body, as set out in claim 4.

Embodiments of the invention will be described below by way of example in conjunction with the attached drawings, with the understanding that some modifications, variations, and changes of the same could be made by the skilled person in the art to which the invention pertains.

In the drawings :

Fig. 1 is a front view of an embodiment of the extruding die according to the present invention as viewed from the extruding side thereof ;

Fig. 2 is a front view of another embodiment of the extruding die according to the present invention as viewed from the extruding side thereof ;

Fig. 3 is a sectional view of Fig. 2 taken along a line III-III' of Fig. 2 ;

Fig. 4 is a sectional view of a further embodiment of the extruding die according to the present invention with a metallic plate attached ;

Fig. 5 is a sectional view of Fig. 1 taken along a line V-V' ;

Fig. 6 is a sectional view of a conventional extruding die ;

Fig. 7 is a sectional view of Fig. 6 taken along a line VIII-VIII', with a cylinder and a fitting frame ;

Fig. 8 is a front view of a ceramic honeycomb structural body shaped according to the pres nt invention ; and

Figs. 9 and 10 are examples of pressure wave type supercharger ceramic rotors produc d by using honeycomb structural bodies extruded according to the present invention, Figs. 9 and 10 b ing a perspective view and a front view thereof, respectively.

As shown in Figs. 1, 2, 3, 4, and 5, a die 1 for extruding ceramic honeycomb structural bodies (hereinafter referred to briefly as "die") according to the present invention mainly comprises ceramic body feed holes (hereinafter referred to briefly as "feed holes") 3 : 3a, 3b, 3c, 3d, and 3e on the side towards an extruding machine, and shaping channels 2 : 2a, 2b, 2c, 2d, and 2e connected to the feed holes and adapted to shape a ceramic body fed through the feed holes into the form of a desired ceramic honeycomb structure. That is, the shaping channels form partition walls, an inner peripheral wall, and an outer peripheral wall of the ceramic honeycomb structural body. Thus, for instance, depending upon the partition walls having different thicknesses, the shaping channels 2a and 2e having a greater shaping width and the shaping channels 2b, 2c and 2d having a smaller shaping width are provided corresponding to thicker partition walls and thinner partition walls, respectively.

The above-constituted die according to the present invention is characterized in that communicating paths of the feed holes 3a and 3e, which communicate with the shaping channels 2a and 2e giving the greater partition wall thickness are bent.

By bending the communicating paths like this, shearing force is applied to the ceramic body fed through the feed holes and at the same time the body is laterally forced out. Consequently, adhesion in the ceramic body becomes greater. Therefore, the thus obtained ceramic honeycomb body is free from defects seen in the above-mentioned conventional techniques.

From the standpoint of adhesion in the body, it is preferable to bend the communicating paths at an angle of 30° or more in the extruding direction. More preferably, the bending angle is 90°. The communicating paths may be bent once, and more preferably twice or more.

As shown in Fig. 3, it may be that the outer peripheral wall of the honeycomb structural body is partially formed by an inner peripheral face of a die-fitting frame 5 for fitting the die 1 to a cylinder 4 of the extruding machine, while the inner peripheral wall is partially formed by an outer peripheral face of a ring piece 5' constituting a part of the die 1.

As shown in Fig. 5, it may be that the outer and inner peripheral walls of the honeycomb structural body are formed by the die by itself, respectively. In addition, as shown in Fig. 4 as a further embodiment, a metal plate 7, which is provided with openings 6a and 6e having a smaller hydraulic diameter and openings 6b, 6c and 6d corresponding to the shaping chann ls 2a and 2e, and 2b, 2c and 2d having the greater shaping width and smaller shaping width, respectiv ly, may be attached, on a side of the cylinder 4, to

the body feed holes 3 having substantially the same hydraulic diameter.

The die for controlling the flowing of the ceramic body with the metallic plate is effectively used when various shaping channel-provided section and feed hole-provided section are separately formed and an appropriate combination thereof is selected depending upon the shape of desired ceramic honeycomb structural bodies or when the flow of the ceramic body is desired to be partially controlled at the shaping channels and/or the feed holes.

As shown in Figs. 3, 4 and 5, the shaping channels may be designed in various sectional shapes and in various arrangements depending on the shape of the ceramic honeycomb structural bodies. The shaping channels may be formed by a conventional technique such as discharge working taking the dimension and material thereof into consideration.

The ratio between the maximum width T_1 and the minimum width T_2 of the shaping channels may be set in a range of $1 < T_1/T_2 \leqq 300$. If the ratio exceeds 300, it is necessary to greatly reduce the dimension of the feed holes corresponding to the wider shaping channels. This renders mechanical working difficult.

The feed holes are formed in the die on the cylinder side of the extruding machine such that they may be located corresponding to intersections or annular portions of the shaping channels. It is necessary to make the hydraulic diameter of the feed holes correspond to the width of the shaping channels.

That is, as shown in Figs. 3 through 5, the feed holes 3a and 3e having the smaller hydraulic diameter connect with the shaping channels 2a and 2e having the greater shaping width, respectively, while the feed hol s 3b, 3c and 3d having the greater hydraulic diameter connect with the shaping channels 2b, 2c and 2d having the smaller shaping width, respectiv ly.

The connection of the feed holes to the shaping channels means herein that the ceramic body coming from the extruding machine is fed into the feed holes through the cylinder 4 and flows inside the shaping channels at right angles relative to the extruding direction, and the body is united inside the shaping channels. In order to unite the ceramic body inside the shaping channels, it is necessary to appropriately sel ct the dimension, number and arrangement of the feed holes such that the shaping channels may fully be filled with the ceramic body. On the other hand, the depth of the shaping channels needs to be large enough to fully charge the body thereinto.

Next, steps of forming ceramic honeycomb structural bodies having partition walls of plural different thicknesses by using the die according to the present invention will be explained.

Th ceramic body inside the cylinder 4 is press fed into the feed holes 3 of the die 1 by the extruder. At that time, since the ceramic body undergoes greater resistance from the inner wall faces of the fed holes 3a and 3e having a smaller hydraulic diameter than from those of the feed holes 3b, 3c and 3d having the greater hydraulic diameter, the ceramic body flows more slowly inside the former. On the other hand, as to the shaping channels 2, the shaping speed of the ceramic body in the shaping channels 2a and 2e having the larger shaping width is greater than in the shaping channels 2b, 2c and 2d having the smaller shaping width. That is, the extruding speed of the ceramic body at the front face of the die is complementally controlled by the dimensions of the feed holes and the shaping channels so that the thinner and thicker partition wall portions of the honeycomb structural body may be extruded at the same shaping speed.

Furthermore, since the communicating paths of the feed holes 3a and 3e, which connect and communicate to the shaping channels 2a and 2e giving the thicker partition walls are bent, the ceramic body laterally flows in the shaping channels so that the ceramic body ceramic body is united together with great adhesion. Thus, a mechanically strong green ceramic honeycomb structural body as shown in Fig. 8 can be obtained. Then, the green body is fired, thereby obtaining a crack-free pressure wave type supercharger ceramic rotor shown in Figs. 9 and 10.

Next, more specific examples of the present invention will be explained.

Examples

Five parts by weight of powdery magnesium oxide, 4.2 parts by weight of powdery cerium oxide, and 0.8 parts by weight of powdery strontium oxide were added, as a sintering aid, to 90 parts by weight of powdery silicon nitride having the average particle diameter of 5.0 µm, thereby obtaining 100 parts by weight of a ceramic powder. The thus obtained ceramic powder was kneaded with 6 parts by weight of an organic binder mainly consisting of methyl cellulose as a shaping aid and 23 parts by weight of water. The kneaded material to be extruded was extruded by a die 1 shown in Fig. 3, thereby obtaining an extruded body having an outer diameter of 140 mm and a length of 200 mm. In this die, the width of the shaping channels 2a, 2e giving the outer and inner peripheral partition walls was 5 mm, and that of the shaping channels 2b, 2c and 2d giving the partition walls constituting cells was 2b = 2d = 0.7 mm, and 2c = 1.0 mm. A body having a length of 10 mm in an extruding direction was cut from the thus extruded body. Although defects contained in the outer and inner peripheral walls were checked by an X-ray radiographic inspection, no such d fects were found.

Next, after 30% of water was removed from the remaining extruded ceramic body by using an electric range, water was compl tely removed by blowing hot

air at 70°C through holes.

Thereafter, the dried body was calcined at 500°C in air to remove the organic binder, which was fired at 1,750°C for 2 hours in a nitrogen atmosphere, thereby obtaining a sintered body.

By using a diamond wheel, this sintered body was machined at the outer and inner peripheral portions and the end faces thereof to attain a desired shape, thereby obtaining a pressure wave type supercharger ceramic rotor.

Although occurrence of defects such as cracks was visually checked, almost no defects were found in this rotor.

For comparison , a ceramic body was extruded under the same conditions as mentioned above using the conventional die shown in Figs. 6 and 7, thereby obtaining an extruded body having an outer diameter of 140 mm. A body having a length of 10 mm in an extruding direction was cut from the thus extruded body, and the outer and inner peripheral walls were inspected as to their inner defects by the X-ray radiographical inspection. Consequently, inner defects were found out in both the outer and inner peripheral walls. A ceramic rotor was obtained by drying, firing and grinding the remaining extruded body. It was revealed that scratch-like cracks parallel in the extruding direction and arcuate cracks representing flow of the body occurred in the rotor.

As detailed above, in the extruding die according to the present invention, the hydraulic diameter of the ceramic body feed holes communicating with the shaping channels giving the smaller partition wall thickness is made greater than that of the ceramic body feed holes communicating with the shaping channels giving the greater partition wall thickness, and the communicating paths of the ceramic body feed holes, which connect to and communicate with the shaping channels giving the thicker partition walls are bent. Thereby, shearing force is applied to the ceramic body there so that the ceramic body is united with great adhesion. Thus, the invention has a great advantage that mechanically strong ceramic honeycomb structural bodies can be obtained.

Claims

1. A die for extruding ceramic honeycomb structural bodies having a plurality of through holes with partition walls having a plurality of different thicknesses, said extruding die comprising a planar exit face, shaping channel (2) ending at said planar exit face and corresponding to the sectional configuration of the ceramic honeycomb structural bodies, and ceramic body feed holes (3) communicating with the shaping channels (2) at junctions thereof, wherein th hydraulic diameter of first ones of said ceramic body feed holes (3b, 3c, 3d) communicating with first ones of said shaping channels (2b, 2c, 2d) providing thinner partition walls is greater than that of second said ceramic body feed holes (3a, 3e) communicating with second said shaping channels (2a, 2e) providing thicker partition walls, and said second shaping channels (2a, 2e) extend in the axial direction of the die from said junctions to said exit face, characterized in that at the junctions of the second feed holes (3a, 3e) with the second shaping channels (2a, 2e), the communicating paths of the second feed holes with the second shaping channels are bent.

2. A die according to claim 1 wherein said bent communicating paths comprise path portions extending at an angle to the respective shaping channels.

3. A die according to claim 1 wherein said bent communicating paths comprise path portions extending at right angles to the respective shaping channels.

4. A die according to any one of claims 1 to 3 wherein said second feed holes (3a, 3e) are parallel to and laterally offset relative to their respective shaping channels.

5. A method for extruding ceramic honeycomb structural bodies from a ceramic body, in which thinner and thicker partition walls of the ceramic honeycomb structural bodies are extruded at the same extruding speed, wherein a die according to any one of claims 1 to 4 is used.

Patentansprüche

1. Mundstück zum Extrudieren keramischer Wabenstrukturkörper mit einer Vielzahl von Durchgangsöffnungen mit Zwischenwänden, welche eine Vielzahl von verschiedenen Dicken aufweisen, dabei umfasst das Mundstück zum Extrudieren eine planare Ausgangsfläche, einen an der planaren Ausgangsfläche endenden und mit der abschnittweisen Anordnung der keramischen Wabenstrukturkörper korrespondieren formenden Kanal (2) und mit den formenden Kanälen (2) an deren Verbindungen kommunizierende, den keramischen Körper zuführende Löcher (3), bei welchen der hydraulische Durchmesser von ersten, der mit ersten der formenden Kanäle (2b, 2c, 2d) kommunizierenden, dünnere Zwischenwände ausbildenden, den keramischen Körper zuführenden Löchern (3b, 3c, 3d) größer ist, als der Durchmesser von zweiten, mit zweiten formenden Kanälen (2a, 2e) kommunizierenden, dickere Zwischenwände ausbildende, den keramischen Körper zuführenden Löchern (3a, 3e), und wobei die zweiten der formenden Kanäle (2a, 2e) sich in axialer Richtung des Mundstücks von den Verbindungen zur Ausgangsfläche erstrecken, gekennzeichnet dadurch, daß an d n Verbindungen der zweiten zuführenden Löcher (3a, 3e) mit den zweiten formenden Kanälen (2a, 2), die kommunizierenden Pfade geknickt sind.

2. Mundstück gemäß Anspruch 1, bei welchem

die geknickten kommunizierenden Pfade Pfadbereiche umfassen, die sich mit einem Winkel zu den zugehörigen formend n Kanälen erstrecken.

3. Mundstück g mäß Anspruch 1, b i welchem geknickte kommunizierende Pfade Pfadbereiche umfassen, welche sich im rechten Winkel zu den zugehörigen formenden Kanälen erstrecken.

4. Mundstück gemäß einem der Ansprüche 1 bis 3, bei welchem die zweiten zuführenden Löcher parallel und lateral relativ zu ihren zugehörigen formenden Kanälen versetzt sind.

5. Verfahren zum Extrudieren keramischer Wabenstrukturkörper aus einem keramischen Körper, bei welchem dünnere und dickere Zwischenwände der keramischen Wabenstrukturkörper mit der selben Extrudiergeschwindigkeit unter Verwendung eines Mundstückes gemäß einem der Ansprüche 1 bis 4 extrudiert werden.

Revendications

1. Une matrice pour l'extrusion de corps céramiques structurels en nid d'abeilles, ayant une pluralité de trous passant à travers tout le corps, avec des cloisons ayant une pluralité d'épaisseurs différentes, ladite matrice d'extrusion comprenant une face de sortie plane, un canal de moulage (2) se terminant à ladite face de sortie plane, et correspondant à la configuration en coupe des corps céramiques structurels n nid d'abeilles, et des orifices d'alimentation en masse céramique (3) communiquant avec les canaux de moulage (2) à des jonctions de ceux-ci, dans laquelle le diamètre hydraulique des premiers desdits rifices d'alimentation de masse céramique (3b, 3c, 3d) communiquant avec les premiers desdits canaux de moulage (2b, 2c, 2d) procurant des cloisons d'épaisseur moindre est plus grand que celui desdits seconds orifices d'alimentation en masse céramique (3a, 3e) communiquant avec lesdits deuxièmes canaux de moulage (2a, 2e) procurant des cloisons plus épaisses, et lesdits seconds canaux de moulage (2a, 2e) s'étendent dans la direction axiale de la matrice à partir desdites jonctions à ladite face de sortie, caractérisée en ce qu'aux jonctions des seconds orifices d'alimentation (3a, 3e) avec les seconds canaux de moulage (2a, 2e), les tronçons de communication des seconds orifices d'alimentation avec les seconds canaux de moulage sont courbés.

2. Une matrice selon la revendication 1 dans laquelle lesdits tronçons de communication courbés comprennent des portions de tronçon qui s'étendent à un certain angle par rapport aux canaux de moulage respectifs.

3. Une matrice selon la revendication 1 dans laquelle lesdits tronçons de communication courbés comprennent des portions de tronçon s'étendant à angle droit par rapport aux canaux de moulage respectifs.

4. Une matrice selon une quelconque des revendications 1 à 3, dans laquelle lesdits seconds orifices d'alimentation (3a, 3e) s nt parallèles et latéralement décalés par rapport à leurs canaux de moulage respectifs.

5. Une méthode d'extrusion de corps céramiques structurels en nid d'abeilles à partir d'une masse céramique, dans laquelle les cloisons plus minces et plus épaisses des corps céramiques structurels en nid d'abeilles sont extrudées à la même vitesse d'extrusion, dans laquelle une matrice selon une quelconque des revendications 1 à 4 est utilisée.

FIG_1

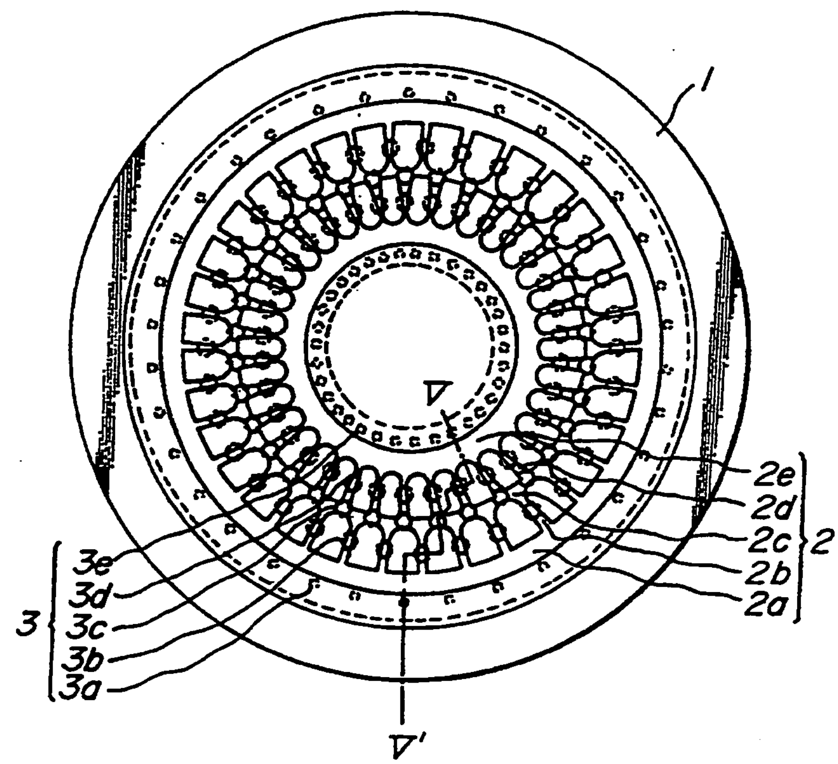

FIG_2

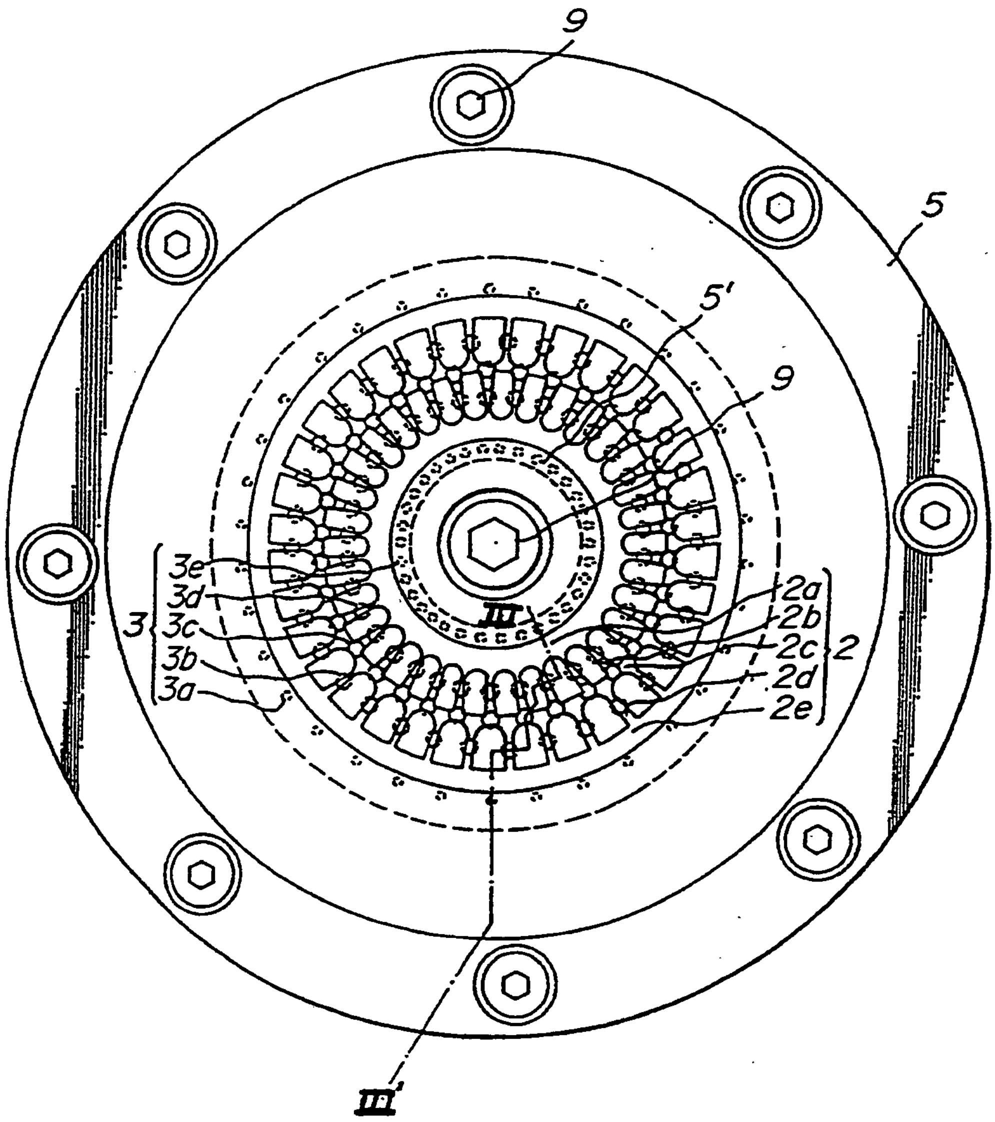

FIG_3

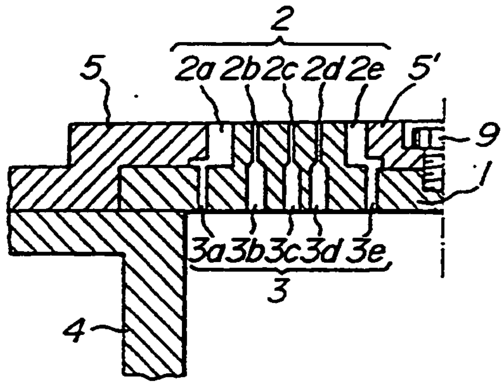

FIG_4

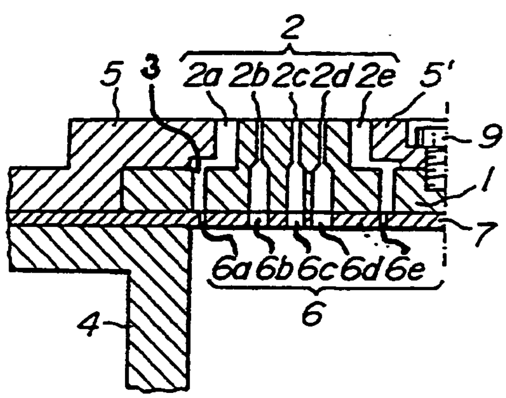

FIG_5

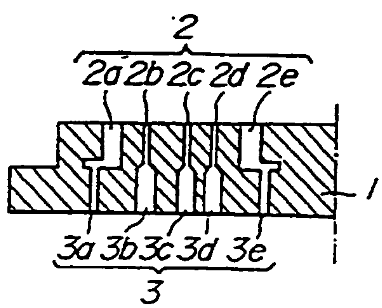

FIG_6

PRIOR ART

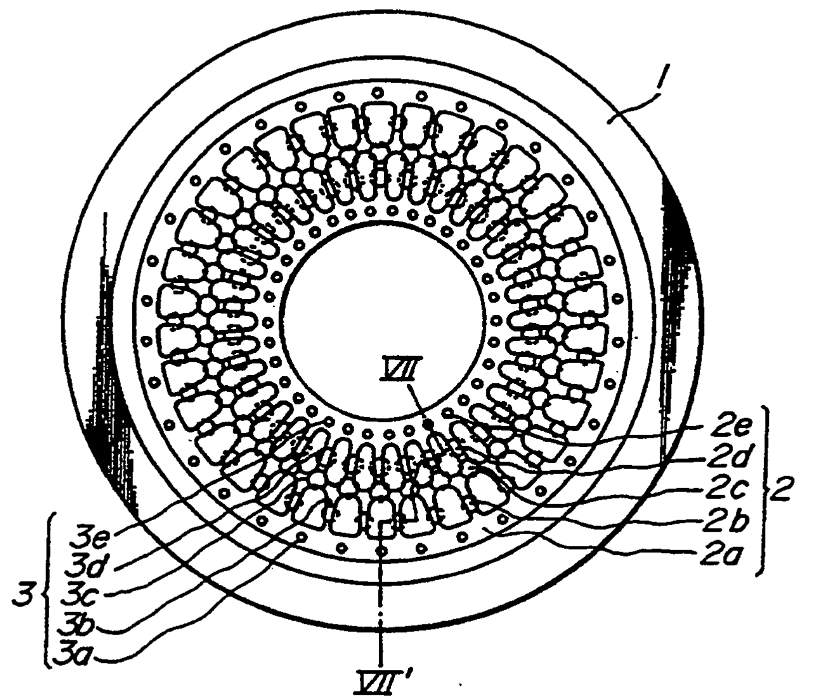

FIG_7

PRIOR ART

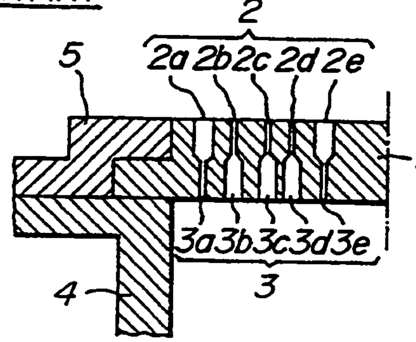

FIG_8

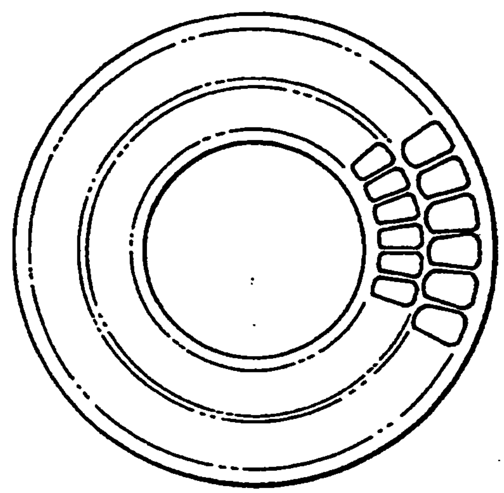

FIG_9

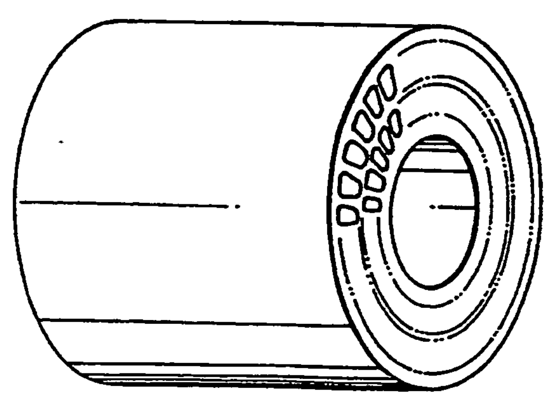

FIG_10